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High frequency ultrasonic devices for the evaluation of the viscosity of coconut water in a rapid and simple way

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Coconut Water
- Natural functional drink
- Concentration to increase SSC*
- Key parameter: viscosity

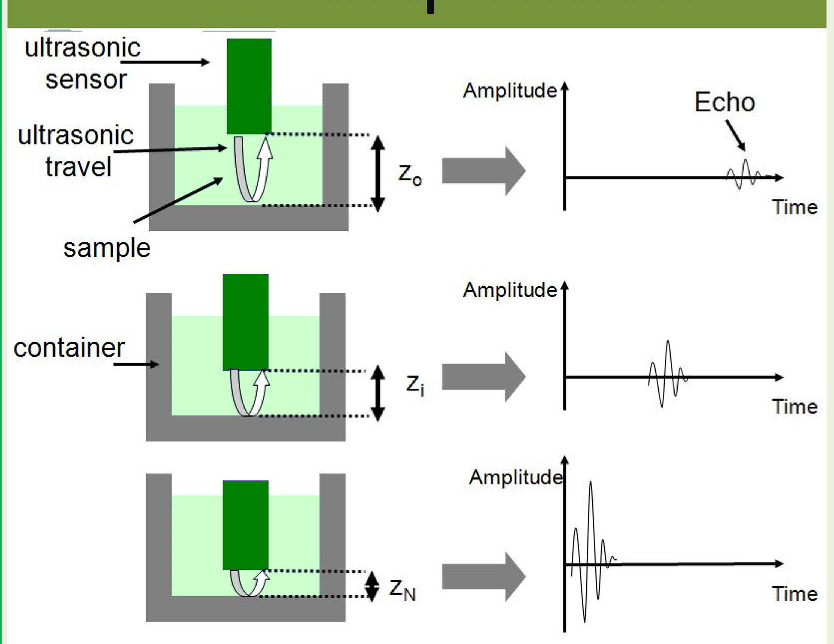
*(Soluble Solids Content)

Interest of ultrasonic approaches

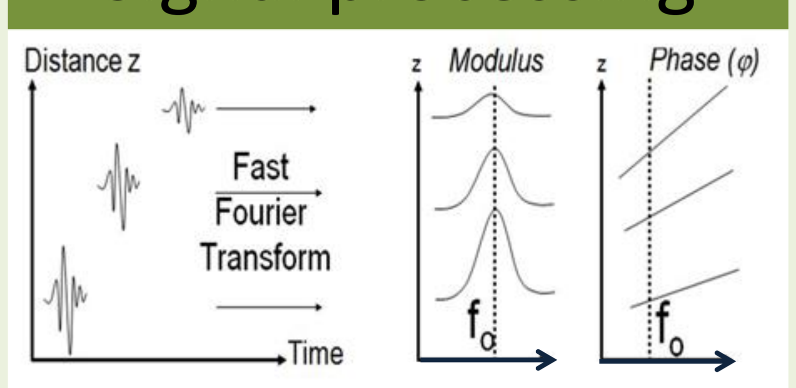
Non destructive - Measurements on small volumes - Applicable « on line »

LONGITUDINAL WAVES (5 MHz – 30 MHz)

Data acquisition



Signal processing



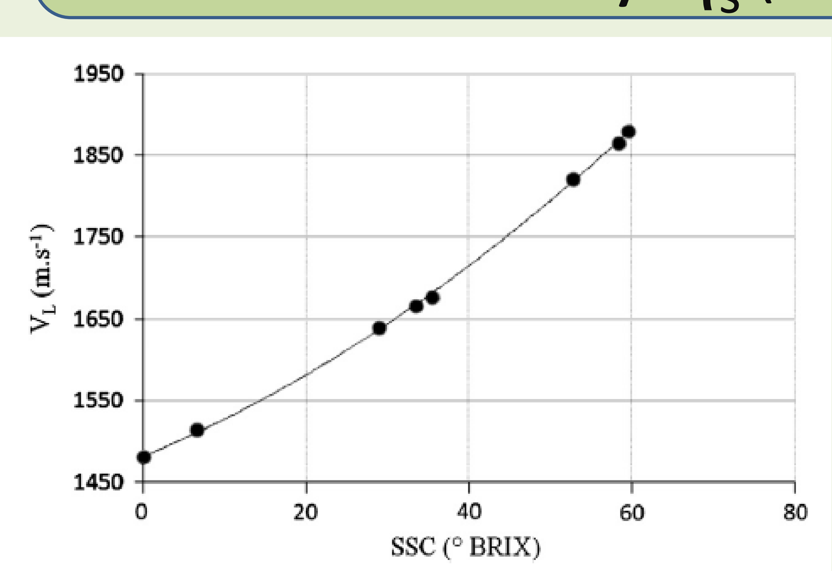
Ultrasonic velocity (V_L) and attenuation (α_L) versus frequency

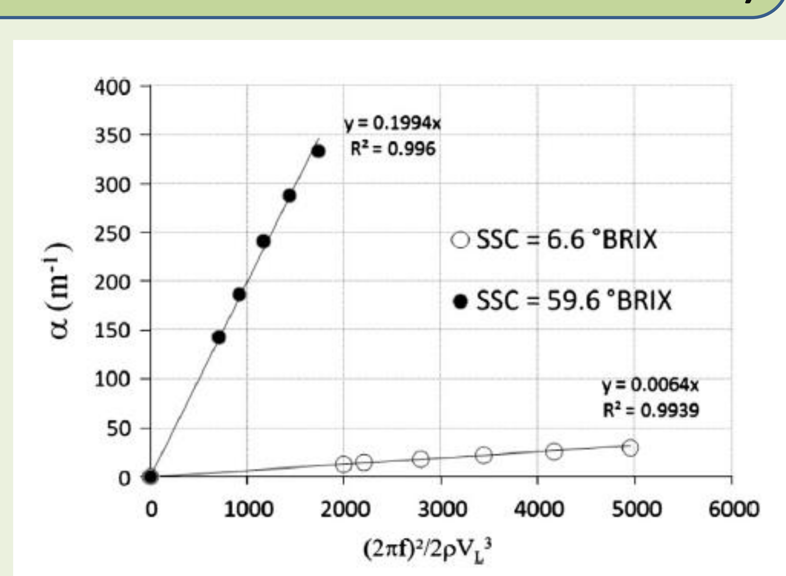
Longitudinal viscosity estimation

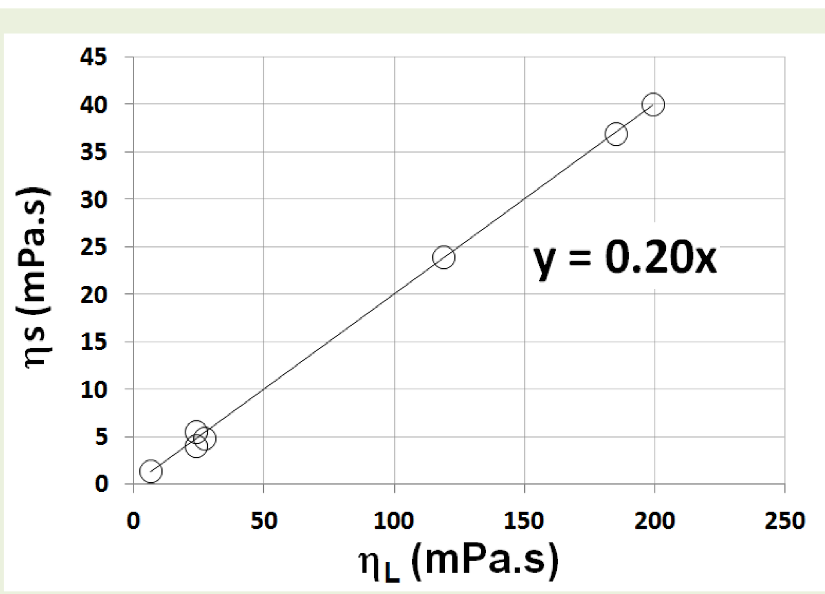
$$\eta_L \approx \frac{2\alpha_L \rho V_L^3}{(2\pi.f)^2}$$

With
α_L : longitudinal attenuation
ρ : density
V_L : longitudinal velocity
f : frequency

Relationship between longitudinal viscosity & shear viscosity η_s (measured with a viscosimeter)





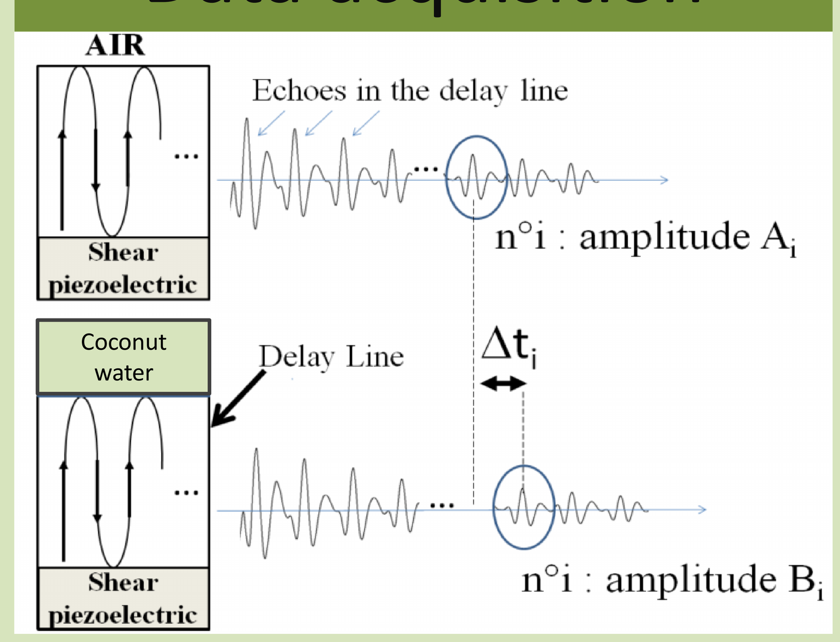


$$\eta_s \sim 0.2\ \eta_L$$

Applicable on line during coconut water concentration and to any other viscous fluid

SHEAR WAVES (5 MHz – 20 MHz)

Data acquisition



Signal processing

-Plot of $\ln(B_i/A_i) = f(i)$ for i=1..N
-Linear adjustment
-Slope : p

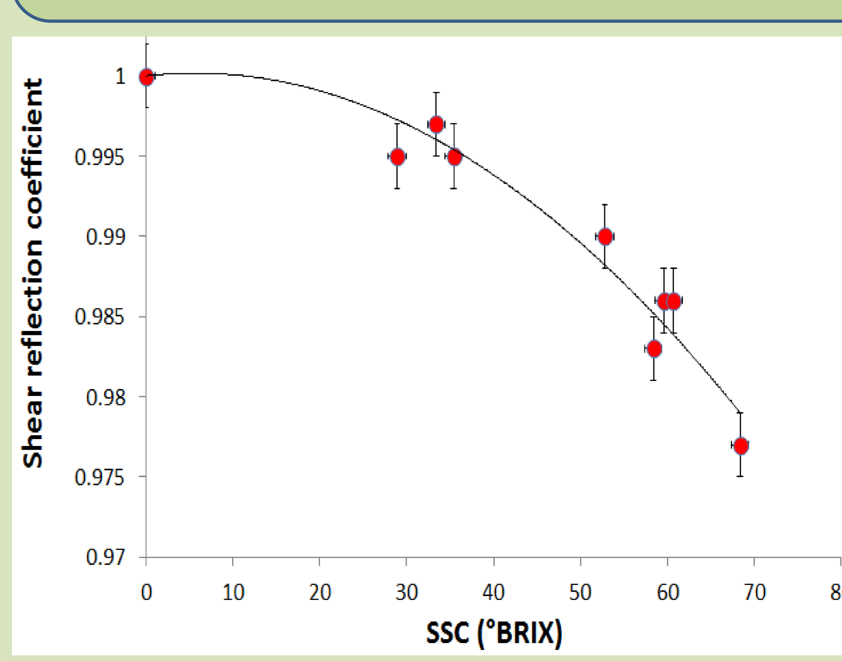
The shear reflection coefficient R is given by e^P

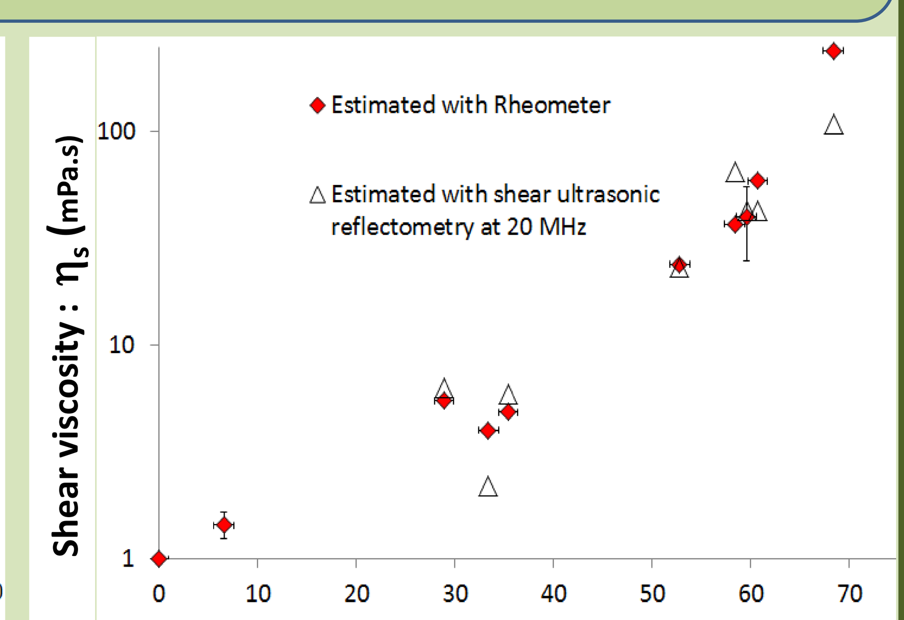
Shear viscosity estimation (hypothesis: Newtonian fluid)

$$(\rho.\eta_s)^{0.5} = Z.(2/\omega)^{0.5}\ \frac{1-R}{1+R}$$

With
ρ : density
ω : $2.\pi$.frequency
Z : shear acoustical impedance of the delay line = $\rho_{(DL)} . V_{s(DL)}$

Comparison between ultrasonic approach & viscosimeter measurements





Direct estimation of shear viscosity

Newtonian behaviour (agreement between low & high frequency)

Applicable to off-line portable devices such as refractometers